9. $B = F/qv = (6.8 \times 10^{-13}\ \mathrm{N})/[(1.6 \times 10^{-19}\ \mathrm{C})(3.4 \times 10^5\ \mathrm{m/s})] = \underline{12.5\ \mathrm{T}}$.
Direction is <u>west</u>.

10. $F = qvB = mv^2/r$
$v = qrB/m = (1.6 \times 10^{-19}\ \mathrm{C})(8.45 \times 10^{-3}\ \mathrm{m})(1.4\ \mathrm{T})/(1.67 \times 10^{-27}\ \mathrm{kg}) = 1.13 \times 10^6\ \mathrm{m/s}$.
$E = mv^2/2 = (1.67 \times 10^{-27}\ \mathrm{kg})(1.13 \times 10^6\ \mathrm{m/s})^2/2 = 1.066 \times 10^{-15}\ \mathrm{J} \times (1\ \mathrm{eV}/1.6 \times 10^{-19}\ \mathrm{J})$
$= \underline{6.66\ \mathrm{keV}}$.

11. $Bqv = mv^2/r$. $p = mv = qBr$.

12. $F = qvB = mv^2/r$
$v = qrB/m$
$E_K = mv^2/2 = m/(qvB)\dfrac{m}{2}\left[\dfrac{qrB}{m}\right]^2 = mq^2r^2B^2/2$
So E_K is proportional to r^2.

13. $E_K = 6000\ \mathrm{eV}(1.6 \times 10^{-19}\ \mathrm{J/eV}) = 9.6 \times 10^{-16}\ \mathrm{J}$
$v = (2E_K/m)^{\frac{1}{2}} = [2(9.6 \times 10^{-16}\ \mathrm{J})/(9.11 \times 10^{-31}\ \mathrm{kg})]^{\frac{1}{2}} = 4.59 \times 10^7\ \mathrm{m/s}$
$qvB = mv^2/r$
$B = \dfrac{mv}{qr} = (9.11 \times 10^{-31}\ \mathrm{kg})(4.59 \times 10^7\ \mathrm{m/s})/[(1.6 \times 10^{-19}\ \mathrm{C})(0.0084\ \mathrm{m})] = \underline{3.11 \times 10^{-2}\ \mathrm{T}}$.

14. Time $= 700\ \mathrm{m}/(200\ \mathrm{m/s}) = 3.5\ \mathrm{s}$.
$F = qvB = (6.80 \times 10^{-9}\ \mathrm{C})(200\ \mathrm{m/s})(5.0 \times 10^{-5}\ \mathrm{T}) = 6.8 \times 10^{-11}\ \mathrm{N}$
$a = F/m = (6.8 \times 10^{-11}\ \mathrm{N})/(4.70 \times 10^{-3}\ \mathrm{kg}) = 1.45 \times 10^{-8}\ \mathrm{m/s^2}$
$d = at^2/2 = (1.45 \times 10^{-8}\ \mathrm{m/s^2})(3.5\ \mathrm{s})^2/2 = \underline{8.86 \times 10^{-8}\ \mathrm{m}}$

15. $Eq = qvB$. But $E = \mathcal{E}/\ell$. Hence $\mathcal{E} = \underline{vB\ell}$.

16. (a) Both positive and negative ions feel a force in the same direction.

(b) $qE = qvB$
$v = E/B = (V/d)/B = V/dB = (0.10 \times 10^{-3}\ \mathrm{V})/[(3.3 \times 10^{-3}\ \mathrm{m})(0.70\ \mathrm{T})] = 0.433\ \mathrm{m/s}$.

17. Use Eq. 20-6.$\phi = NIAB/k$.
So $I_2 = I_1(B_1/B_2) = (48\ \mathrm{mA})(B_1/0.9\ B_1) = \underline{53.3\ \mu\mathrm{A}}$.

18. Use Eq. 20–6. $\phi = NIAB/k$.
So $I_2 = I_1(k_2/k_1) = (38 \text{ mA})(0.85\ I_1/I_1) = \underline{32.3\ \mu\text{A}} = \underline{32\ \mu\text{A}}$.

19. $\tau = NIAB$. $\tau_2 = \tau_1(I_2/I_1) = \tau_1(.90\ I_1/I_1) = \underline{0.9\ \tau_1}$.

20. $\tau = NIAB$, $B = \tau/NIA = (0.378 \text{ N}\cdot\text{m})/[(1)(4.5 \text{ A})(0.17 \text{ m})^2] = \underline{2.91 \text{ T}}$.

21. $\tau = Fb \sin\alpha$ where α is angle between force and lever arm. $F = IaB$.
$\tau = IabB \sin\alpha = IAB \sin\alpha$. In this question $\theta = 90 - \alpha$. $\tau = NIAB \cos\theta$ if N loops.

22. (a) $\tau = NIAB \cos\theta$, from Problem 21.
$= (5)(25 \text{ A})\pi(0.26 \text{ m}/2)^2(6.1 \times 10^{-5} \text{ T})\cos(46°) = \underline{2.81 \times 10^{-4} \text{ N}\cdot\text{m}}$.

(b) The North edge rises.

23. $V = E/B$ and $BqV = mV^2/r$. $(q/m) = E/rB^2 = (200 \text{ V/m})/(8 \times 10^{-3} \text{ m})/(0.46 \text{ T})^2 = \underline{1.18 \times 10^5 \text{ C}/}$

24. $qvB = mv^2/r$
$v = qrB/m = (1.6 \times 10^{-19} \text{ C})(0.052 \text{ m})(0.465 \text{ T})/(1.67 \times 10^{-27} \text{ kg}) = 2.32 \times 10^6 \text{ m/s}$.
$qvB = qE$, $E = vB = (2.32 \times 10^6 \text{ m/s})(0.465 \text{ T}) = \underline{1.08 \times 10^6 \text{ V/m}}$.
The E–field must be perpendicular to the magnetic field in the plane of the circle.

25. $Eq = qvB$. $v = E/B = (8.85 \times 10^3 \text{ V/m})/(4.5 \times 10^{-3} \text{ T}) = \underline{1.97 \times 10^6 \text{ m/s}}$.
$qvB = mv^2/r$
$r = mv/qB = (9.11 \times 10^{-31} \text{ kg})(1.97 \times 10^6 \text{ m/s})/[(1.6 \times 10^{-19} \text{ C})(4.5 \times 10^{-3} \text{ T})] = \underline{2.49 \text{ mm}}$.

26. $mg = NeE$. $N = (3.3 \times 10^{-15} \text{ kg})(9.8 \text{ m/s}^2)/(1.6 \times 10^{-19} \text{ C})/(340 \text{ V}/10^{-2} \text{ m}) = 5.94$, i.e. 6 electrons.

27. $mg = (4\pi/3)r^3(\rho - \rho_A)g = 6\pi\eta r v_T$. Hence $r = 3[\eta v_T/(\rho - \rho_A)g]^{\frac{1}{2}}$. But $q = mg/E = 6\ \pi\eta r v_T d/V$.
Substituting for r gives the desired result.

$v = (3\ kT/m)^{\frac{1}{2}}$. Firstly $v = [(3 \times 1.38 \times 10^{-23}\ \mathrm{J/K})(300\ \mathrm{K})/(9.11 \times 10^{-31}\ \mathrm{kg})]^{\frac{1}{2}}$ l= $\underline{1.17 \times 10^{5}\ \mathrm{m/s}}$.

Secondly $v = 1.17 \times 10^{5}\ \mathrm{m/s}(2500\ \mathrm{K}/300\ \mathrm{K})^{\frac{1}{2}} = \underline{3.37 \times 10^{5}\ \mathrm{m/s}}$.

29. Let ℓ be distance traveled in deflecting plates aligned in direction x.

$v_x = \left[\frac{2q\Delta V}{m}\right]^{\frac{1}{2}}$. v_y after deflection $= at = \left[\frac{qE}{m}\right]\frac{\ell}{v_x}$.

Hence if θ is deflection angle, $\tan\theta = \frac{v_y}{v_x} = \left[\frac{qE\ell}{m}\right]\left[\frac{m}{2q\Delta V}\right] = \frac{E\ell}{2\Delta V}$

Hence $E = \frac{2\Delta V}{\ell}\tan\theta$.

Hence $\tan\theta = \frac{12\ \mathrm{cm}}{25\ \mathrm{cm}} = 0.48$.

Hence $E = \frac{2(10^{4}\ \mathrm{V})}{0.024\ \mathrm{m}}(0.48) = \underline{4 \times 10^{5}\ \mathrm{N/C}}$.

It must of course reverse to sweep the other half of screen.

30. Let ℓ be distance traveled in deflecting plates aligned in direction x.

$v_x = \left[\frac{2q\Delta V}{m}\right]^{\frac{1}{2}}$. v_y after deflection $= at = \left[\frac{qv_xB}{m}\right]\left[\frac{\ell}{v_x}\right]$.

Hence if θ is deflection angle, $\tan\theta = \frac{v_y}{v_x} = \frac{qB\ell}{mv_x} = B\ell\left[\frac{q}{2m\Delta V}\right]^{\frac{1}{2}}$

Hence $B = \frac{\frac{11\ \mathrm{cm}}{22\ \mathrm{cm}}}{(0.028\ \mathrm{m})}\left[\frac{(2)(9.11 \times 10^{-31}\ \mathrm{kg})(15 \times 10^{3}\ \mathrm{V})}{1.6 \times 10^{-19}\ \mathrm{C}}\right]^{\frac{1}{2}} = \underline{7.38 \times 10^{-3}\ \mathrm{T}}$.

31. $m = qBB'r/E$, i.e. m is proportional to r. Thus $m' = m(r'/r) = (76\ \mathrm{u})(21\ \mathrm{cm}/22.8\ \mathrm{cm}) = \underline{70\ \mathrm{u}}$. Similarly 21.6 gives 72 u. 21.9 gives 73 u. 22.2 gives 74 u.

32. The separation is $2\Delta r = \frac{2E\Delta m}{qBB'} = \frac{2(2.48 \times 10^{4}\ \mathrm{V/m})(1.67 \times 10^{-27}\ \mathrm{kg/u})(1\ \mathrm{u})}{(1.6 \times 10^{-19}\ \mathrm{C})(0.75\ \mathrm{T})^{2}} = \underline{9.2 \times 10^{-4}\ \mathrm{m}}$.

33. $D = 2\Delta r = \frac{2(\Delta mE)}{qBB'} = 2\left[\frac{\Delta m}{m}\right]r$, i.e. $r = \frac{mD}{2\Delta m}$

$r = \frac{(28.0106\ \mathrm{u})(0.33 \times 10^{-3}\ \mathrm{m})}{2(0.0028\ \mathrm{u})} = \underline{1.65\ \mathrm{m}}$.

34. $F = qvB = mv^2/R$. $v = (qBR/m)$.

By conservation of energy $v = (2\ E/m)^{\frac{1}{2}} = (2\ qV/m)^{\frac{1}{2}}$. Hence $2\ qV/m = q^2B^2R^2/m^2$ and $m = qB^2R^2/2V$.

35. $B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{(4\pi \times 10^{-7}\ \mathrm{T\cdot m/A})(3.8\ \mathrm{A})}{2\pi(0.08\ \mathrm{m})} = \underline{9.50 \times 10^{-6}\ \mathrm{T}}$.

36. $B = \mu_0 I/2\pi r$. $I = (10^{-3}\ \mathrm{T})(2\ \pi)(0.3\ \mathrm{m})/(4\pi \times 10^{-7}\ \mathrm{T\cdot m/A}) = \underline{1500\ \mathrm{A}}$.

37. $B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{(2 \times 10^{-7}\ \mathrm{T\cdot m/A})(30\ \mathrm{A})}{(0.075\ \mathrm{m})} = 8 \times 10^{-5}\ \mathrm{T}$.

$a = \dfrac{F}{m} = \dfrac{qvB}{m} = \dfrac{(8\ \mathrm{C})(1.6\ \mathrm{m/s})(8 \times 10^{-5}\ \mathrm{T})}{(0.3\ \mathrm{kg})} = 3.41 \times 10^{-3}\ \mathrm{m/s^2}$.

$a = \underline{3.48 \times 10^{-4}\ g}$.

38. $B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{(2 \times 10^{-7}\ \mathrm{T\cdot m/A})(25\ \mathrm{A})}{(0.1\ \mathrm{m})} = 5 \times 10^{-5}\ \mathrm{T}$.

The electron is travelling at 45° to the wire. But, in the plane of the wire and electron, the ld due to the wire is $\perp$ to plane, so $v \perp B$ and $\sin 90° = 1$.
$F = qvB \sin\theta = (1.6 \times 10^{-19}\ \mathrm{C})(8.5 \times 10^5\ \mathrm{m/s})(5 \times 10^{-5}\ \mathrm{T}) = \underline{6.80 \times 10^{-18}\ \mathrm{N}}$.

39. $B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{(2 \times 10^{-7}\ \mathrm{T\cdot m/A})(20\ \mathrm{A})}{(0.12\ \mathrm{m})} = 3.33 \times 10^{-5}\ \mathrm{T}$. This points west.

The compass points W $\tan^{-1} \dfrac{0.45 \times 10^{-4}\ \mathrm{T}}{3.33 \times 10^{-5}\ \mathrm{T}}$ N = $\underline{53.5°\ \text{North of west}}$.

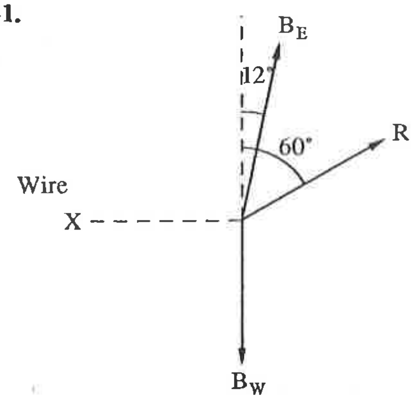
40. (a) If the currents are in the same direction, the fields oppose each other,

$$B = \frac{\mu_0(I - 20)}{2\pi r}.$$

$$B = \frac{(2 \times 10^{-7})(20 - I)}{0.01\ \mathrm{m}} = \underline{2 \times 10^{-5}(20 - I)\ \mathrm{T}}.$$

(b) In opposite directions, $B = \underline{2 \times 10^{-5}(20 + I)\ \mathrm{T}}$.

41.



First let us find B field produced by wire B_W. It must be south. Take components perpendicular to the resultant.
$B_W(\sin 60^\circ) = B_E \sin 48^\circ$
$B_W = 4.29 \times 10^{-5}$ T.

The current has magnitude $\frac{B_W r 2\pi}{\mu_0} = \frac{(4.29 \times 10^{-5}\ \text{T})\ (0.1\ \text{m})}{(2 \times 10^{-7}\ \text{T}\cdot\text{m/A})}$ = 21.5 A and is down.

42. $B = \mu_0 In = \mu_0 I\frac{N}{\ell}$

Hence $N = \frac{(0.2\ \text{T})(0.28\ \text{m})}{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(8.8\ \text{A})}$ = 5064 turns.

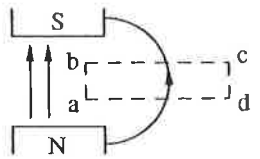
43. First consider constant current operation. $B = \mu_0 IN/L$. Assume wire has cross section $a \times a$ and length ℓ. the $\ell a^2 = V_0$ volume of wire and is fixed. $L = Na$ if wires are closely wound.
$B = \mu_0 I/a$ so we need to make wires as thin as possible. Note $N2\pi r = \ell = V_0/a^2$, so for fixed r, N increases as the inverse of square a, and the length of the solenoid Na increases like a^{-1} as a gets smaller.

44. (a) Taking Path 1, $\Delta\ell = 2\pi r$, and total current is NI. $\Sigma B\Delta\ell = \mu_0 I_{TOT}$, so $B(2\pi R) = \mu_0 NI$, so $B = \mu_0 NI/2\pi r$.

(b) Taking Path 2, net current cutting the circle is zero. So $B = 0$.

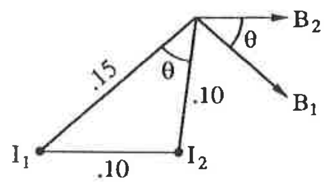
(c) No, the interior field is not uniform, as it depends on r.

45.



There is no current enclosed so we should get zero. If the field lines remained vertical only 'ab' part of path integral would contribute. As this is positive it could not sum to zero. The curved lines give negative contributions from bc and da which cancel properly the positive ab contribution.

46.



From figure, $\cos\theta = \dfrac{0.1^2 + 0.15^2 - 0.1^2}{2(0.15)(0.1)} = 0.75$

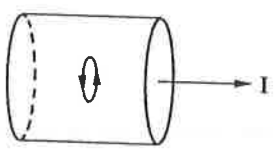
$$B_2 = \frac{(2\times 10^{-7}\ \mathrm{T\cdot m/A})(25\ \mathrm{A})}{0.1\ \mathrm{m}} = 5\times 10^{-5}\ \mathrm{T}$$

$$B_1 = \frac{(2\times 10^{-7}\ \mathrm{T\cdot m/A})(25\ \mathrm{A})}{0.15\ \mathrm{m}} = 3.33\times 10\text{-}5\ \mathrm{T}$$

Hence resultant field is $(B_1^2 + B_2^2 + 2B_1B_2\cos\theta)^{\frac{1}{2}}$

$$= [(5\times 10^{-5}\ \mathrm{T})^2 + (3.33\times 10^{-5}\ \mathrm{T})^2 + 2(5\times 10^{-5}\ \mathrm{T})(3.33\times 10^{-5}\ \mathrm{T})(0.75)]^{\frac{1}{2}}$$
$$= \underline{7.82\times 10^{-5}\ \mathrm{T}}.$$

47.



Take a loop inside the conductor as shown. Current enclosed I' is in proportion to the area. $I' = I(r^2/r_0^2)$. Ampere's law gives $2\pi rB = \mu_0 I' = \mu_0 I(r^2/r_0^2)$. $B = \mu_0 Ir/2\pi r_0^2$.

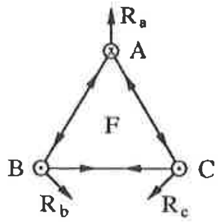
48. $\dfrac{F}{\ell} = \mu_0\dfrac{I_1I_2}{2\pi L}$. Hence $F = \dfrac{(80\ \mathrm{m})(2\times 10^{-7}\ \mathrm{T\cdot m/A})(35\ \mathrm{A})^2}{(0.08\ \mathrm{m})} = \underline{0.245\ \mathrm{N}}$.

The force is <u>attractive</u>.

49. $\dfrac{F}{\ell} = \dfrac{\mu_0 I_1 I_2}{2\pi L}$. Hence, $I_1 = \dfrac{(7\times 10^{-4}\ \mathrm{N/m})(0.08\ \mathrm{m})}{(2\times 10^{-7}\ \mathrm{T\cdot m/A})(9\ \mathrm{A})} = \underline{31.1\ \mathrm{A}}$.

I_2 in the <u>same direction</u> as force is attractive.

50.



Forces F all have the same magnitude $\frac{F}{\ell} = \frac{\mu_0 I^2}{2\pi L}$

$$\frac{F}{\ell} = \frac{\mu_0 I^2}{2\pi L} = \frac{(2\times 10^{-7}\ \mathrm{T\cdot m/A})(3\ \mathrm{A})^2}{(0.27\ \mathrm{m})} = 6.67\times 10^{-6}\ \mathrm{N/m}.$$

Their directions are shown as in figure.
The forces on A are vertically up and equal
$2F\cos 30^\circ = \underline{1.15\times 10^{-5}\ \mathrm{N/m}}$.
The force on B makes an angle of 60° with BC and equals
$2F\cos 60^\circ = 6.67\times 10^{-6}$ N/m.
The force on C similar.

51. (a) $\frac{mg}{\ell} = \frac{\mu_0 I_1 I_2}{2\pi L}$. Thus $I_2 = \frac{(8.9\times 10^3\ \mathrm{kg/m^3})(\pi)(1.25\times 10^{-3}\ \mathrm{m})^2(0.15\ \mathrm{m})(9.8\ \mathrm{m/s^2})}{(2\times 10^{-7}\ \mathrm{T\cdot m/A})(48\ \mathrm{A})}$

$= \underline{6.69\times 10^3\ \mathrm{A}}$ in <u>same direction</u> as it is attractive.

(b) <u>No</u>. If we move it down force of support decreases.

(c) Now $I_2 = 6.69\times 10^3$ N in <u>opposite direction</u>.

<u>Yes</u>, the equilibrium is stable to vertical displacement.

52. $B = \mu\eta I \rightarrow \mu = \frac{(1.8\ \mathrm{T})(0.36\ \mathrm{m})}{(600)(40\ \mathrm{A})} = \underline{2.7\times 10^{-5}\ \mathrm{T\cdot m/A}}$.

53. $F = qvB = (150\ \mathrm{C})(280\ \mathrm{m/s})(5.0\times 10^{-5}\ \mathrm{T}) = 2.10$ N.

54. (a) $\frac{mv^2}{2} = q\Delta V$. $Bq = \frac{mv}{r}$. Hence $r^2 = \frac{2m\Delta V}{B^2 q}$.

$$\text{Hence } r = \left[\frac{(2)(6.7\times 10^{-27}\ \mathrm{kg})(1900\ \mathrm{V})}{(0.34\ \mathrm{T})^2(1.6\times 10^{-19}\ \mathrm{C})(2)}\right]^{\frac{1}{2}} = \underline{2.62\ \mathrm{cm}}$$

$$\text{(b) } V = \left[\frac{2q\Delta V}{m}\right]^{\frac{1}{2}} = \left[\frac{(2)(2)(1.6\times 10^{-19}\ \mathrm{C})(1900\ \mathrm{V})}{6.7\times 10^{-27}\ \mathrm{kg}}\right]^{\frac{1}{2}} = 4.26\times 10^5\ \mathrm{m/s}.$$

$$T = \frac{2\pi r}{v} = \frac{2\pi(0.0262\ \mathrm{m})}{(4.26\times 10^5\ \mathrm{m/s})} = \underline{3.87\times 10^{-7}\ \mathrm{s}}.$$

55. $F = I\ell B = mg = \rho A\ell g$.
$I = \rho\pi d^2 g/4B = (8.9\times 10^3\ \mathrm{kg/m^3})(\pi)(2\times 10^{-3})^2(9.8\ \mathrm{m/s^2})/4/(5\times 10^{-5}\ \mathrm{T}) = \underline{5480\ \mathrm{A}}$.

56. (a) $\vec{F} = \vec{IL} \times \vec{B}$
$F = ILB.$

$$BIL = ma = m\frac{\Delta v}{\Delta t} = \frac{(v - v_0)}{t - t_0}m$$

If $t = 0$ and $v_0 = 0$

$$\underline{V = \frac{BILt}{m}}$$

(b) $F = \mu mg$

Accelerating force in the presence of friction $(BIL - \mu_k mg) = \frac{mv}{t}$.

$$\underline{v = \frac{BILt}{m} - \mu_k gt.}$$

(c) Rod moves to the <u>east</u>.

57. (a) $v = (2q\Delta V/m)^{\frac{1}{2}} = [(2)(1.6 \times 10^{-19}\text{ C})(2 \times 10^3\text{ V})/(9.11 \times 10^{-31}\text{ kg})]^{\frac{1}{2}} = 2.65 \times 10^7\text{ m/s}.$
$F = qvB = (1.6 \times 10^{-19}\text{ C})(2.65 \times 10^7\text{ m/s})(5 \times 10^{-5}\text{ T}) = 2.12 \times 10^{-16}\text{ N}.$
Time to hit screen is $(0.2\text{ m})/(2.65 \times 10^7\text{ m/s}) = 7.55 \times 10^{-9}\text{ s}.$
Deflection is $at^2/2 = (F/m)(t^2)/2 = (2.12 \times 10^{-16}\text{ N})(7.55 \times 10^{-9}\text{ s})^2/(9.11 \times 10^{-31}\text{ kg})/2$
$= 6.63 \times 10^{-3}$ m or <u>6.63 mm</u>.

$D_2 = D_1(\Delta V_1/\Delta V_2)^{\frac{1}{2}} = (6.63\text{ mm})(2\text{ kV}/30\text{ kV})^{\frac{1}{2}} = \underline{1.71\text{ mm}}.$

58. Velocity perpendicular to magnetic field is $(3.5 \times 10^5\text{ m/s})(\sin 6°) = 3.66 \times 10^4\text{ m/s}.$

Hence $r = \frac{mv}{Bq} = \frac{(9.11 \times 10^{-31}\text{ kg})(3.66 \times 10^4\text{ m/s})}{(0.33\text{ T})(1.6 \times 10^{-19}\text{ C})} = \underline{6.31 \times 10^{-7}\text{ m}}.$

Pitch $= (3.5 \times 10^5\text{ m/s})(\cos 6°)T = \frac{(3.48 \times 10^5\text{ m/s})(2\pi)(6.315 \times 10^{-7}\text{ m})}{3.66 \times 10^4\text{ m/s}}$

Pitch $= \underline{3.77 \times 10^{-5}\text{ m}}.$

59. (a) The field must have the same period as the particle, T.
But $Bqv = mv^2/r$ so $(2\pi r/v) = T = 2\pi m/Bq$. Hence $f = 1/T = Bq/2\pi m$.

(b) At each pass (two per revolution) energy gained is qV_0. So $2qV_0$ is energy per revolution.

(c) $v = rBq/m$.
$E = mv^2/2 = r^2B^2q^2/2m = (2\text{ m})^2(0.5\text{ T})^2(1.6 \times 10^{-19}\text{ C})^2/2/(1.67 \times 10^{-27}\text{ kg})$
$= 7.66 \times 10^{-12}\text{ J})/(1.6 \times 10^{-19}\text{ J/eV}) = \underline{47.9\text{ MeV}}.$

(d) Energy increases when "push" is in phase with pass.

60. (a) The maximum tension occurs when loop force is perpendicular to B field and torque is zero. The tension in each of two wires connecting the sides is $\frac{F}{2}$.

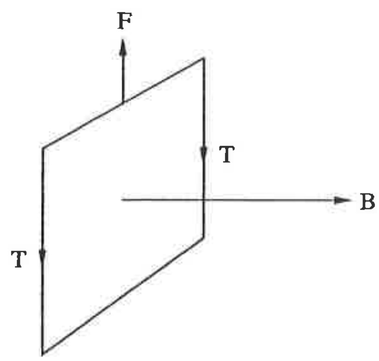
For aluminum shear strength is (200×10^6 N/m^2).

Hence we design $\left[\frac{F}{2A}\right] = 20 \times 10^6$ N/m^2 to allow a factor of 10 in safety.

$$A = \frac{ILB}{40 \times 10^6 \text{ N/m}^2} = \frac{(30 \text{ A})(0.125 \text{ m})(2 \text{ T})}{40 \times 10^6 \text{ N/m}^2} = 1.875 \times 10^{-7} \text{ m}^2$$

Since $A = \frac{\pi d^2}{4}$, we get $d = \underline{4.89 \times 10^{-4} \text{ m}}$.

(b) $R = \frac{\rho L}{A} = \frac{(2.7 \times 10^{-8}\ \Omega\cdot\text{m})(0.125 \text{ m} \times 4)}{1.875 \times 10^{-7} \text{ m}^2} = \underline{0.072\ \Omega}$.



61. Resistance of one loop $= \frac{2\pi r\rho}{A} = \frac{2\pi(0.75 \text{ m})(1.7 \times 10^{-8}\ \Omega\cdot\text{m})}{(2 \times 10^{-3})^2} = 0.02\ \Omega$

$$R = \frac{V^2}{P} = \frac{(60 \text{ V})^2}{1 \times 10^3 \text{ W}} = 3.6\ \Omega.$$

(a) For maximum power supply we need $\left[\frac{3.6\ \Omega}{0.02\ \Omega}\right] = 180$ turns.

(b) $I = \frac{V}{R} = \frac{60 \text{ V}}{3.6\ \Omega} = 16.67$ A.

Thus $B = (4\pi \times 10^{-7} \text{ T}\cdot\text{m/A})(180)\left[\frac{16.67 \text{ A}}{1.5 \text{ m}}\right] = \underline{2.51 \times 10^{-3} \text{ T}}$.

(c) No. If we use more turns but keep V constant I drops, i.e. if we double turns R doubles, but I falls by a factor of 2. The magnetic field however remains the same because the turns increase to compensate for decrease in I.

Chapter 21

1. $\xi = -d\phi/dt = \pi(0.10\text{ m})^2(0.6\text{ T})/(0.10\text{ S}) =$ <u>0.188 V</u>

2. The coil will have a south magnetic pole induced as according to Lenz's law it tries to continue to pull the flux in. Thus a <u>clockwise</u> current is induced.

3. $\xi = 2[25 - (-20)](\text{Wb})/(0.25\text{ s}) =$ <u>360 V</u>

4. $R\uparrow$, $I\downarrow$, $B\downarrow$, i induced as if to oppose change in B, i.e. i <u>counterclockwise</u>.

5. (a) <u>anticlockwise</u>

   (b) <u>clockwise</u>

   (c) <u>anticlockwise</u>

   (d) <u>clockwise</u>

6. (a) $\xi = [0.85\text{ T} - (-0.25\text{ T})](\pi)(0.10\text{ m})^2/(80 \times 10^{-3}\text{ s}) =$ <u>.43 V</u>

   (b) <u>clockwise</u>

7. (a) $\xi = B\ell v = (0.8\text{ T})(0.12\text{ m})(0.15\text{ m/s}) =$ <u>0.0144 V</u>.

   (b) $E = vB = (0.15\text{ m/s})(0.8\text{ T}) =$ <u>0.120 V/m</u>.

8. Viewed from the right the solenoid current is counter clockwise, i.e. the right end is an N–pole. We are therefore pulling an S–pole away from the loops. This change is opposed by an N–pole being induced. This means a counter–clockwise current, i.e. <u>down</u>.

9. (a) $\xi = B\ell v = (0.375\text{ T})(0.24\text{ m})(1.80\text{ m/s}) =$ <u>0.162 V</u>.

   (b) $I = \xi/R = (0.162\text{ V})/(28.5\ \Omega) =$ <u>5.68 mA</u>.

10. $\xi = (8.65 \times 10^{-3}\ \text{T/s})(30)(\pi)(0.175\ \text{m})^2 = 2.50 \times 10^{-2}\ \text{V}$.
$R = \rho\ell/A = (1.68 \times 10^{-8}\ \Omega\cdot\text{m})(30)(2\pi)(0.175\ \text{m})/(\pi)/(1.4 \times 10^{-3}\ \text{m})^2 = 0.090\ \Omega$.

(a) $I = V/R = \underline{277\ \text{mA}}$.

(b) Power $= IV = \underline{6.93 \times 10^{-3}\ \text{W}}$.

11. Mechanically $P = F\text{v} = (I\ell B)\text{v}$. $I = \xi/R$ and $\xi = B\ell\text{v}$ therefore $P = B^2\ell^2\text{v}^2/R$.
Electrically $P = V^2/R = \xi^2/R = B^2\ell^2\text{v}^2/R$.

12. Length of loop in circuit at any time is $\ell + 2\text{v}t$. $R = \rho(\ell + 2\text{v}t)/A$. $\xi = B\ell\text{v}$.
$I = \xi/R = \underline{AB\ell\text{v}/(\ell + 2\text{v}t)\rho}$.

13. $\xi = (\pi)(0.09\ \text{m})^2(0.85\ \text{T})/\Delta t$.
$Q = I\Delta t = E\Delta t/R = (\pi)(0.09\ \text{m})^2(0.85\ \text{T})(\pi)(0.875 \times 10^{-3})^2/(1.68 \times 10^{-8}\ \Omega\cdot\text{m})/(2\pi)/(0.09\ \text{m}) = \underline{5.48\ \text{C}}$.

14. $\xi_2 = \xi_1(\omega_2/\omega_1) = (12\ \text{V})(1800\ \text{rev/min})/(800\ \text{rev/min})$. No need to change rev/min to rad/s.
$\xi_2 = \underline{27\ \text{V}}$.

15. $\xi_0 = NAB\omega = (125)(0.055\ \text{m})^2(0.400\ \text{T})(2\pi)(120\ \text{rev/s}) = \underline{114\ \text{V}}$.

16. $\xi = NAB\omega \sin wt = \xi_0 \sin wt$. Thus $\xi_{rms} = \xi_0/(2)^{\frac{1}{2}}$.

17. $B = (2)^{\frac{1}{2}}(E_{rms})/(NA\omega) = (2)^{\frac{1}{2}}(220\ \text{V})/(200)/(0.3\ \text{m})^2/(2\ \pi)/(60\ \text{rev/s}) = \underline{0.046\ \text{T}}$.

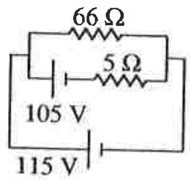
18. $\omega = E_0/NAB = (120\ \text{V})/(300)/(0.25\ \text{m})^2/(0.55\ \text{T})$. Hence $f = \omega/2\pi = \underline{1.85\ \text{rev/s}}$.

19. Counter *emf* $= 120\ \text{V} - IR = 120\ \text{V} - (8.70\ \text{A})(3.40\ \Omega) = \underline{90.4\ \text{V}}$.

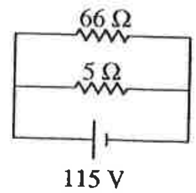
20. $\xi_2 = \xi_1(f_2/f_1) = (80\ \text{V})(2500/1800) = \underline{111\ \text{V}} = \underline{1.1 \times 10^2\ \text{V}}$.

21. The counter *emf* is proportional to the speed, i.e. here it is (108 V)/2 = 54 V.
$I = V/R = (120\ \text{V} - 54\ \text{V})/(5\ \Omega) = 13.2\ \text{A}$.

22. a)



at full speed



at start up

(b) $R = R_1R_1/(R_1 + R_2) = 4.65\ \Omega$. Initially $V = 115$ V, $I = (115\ \text{V})/(4.65\ \Omega) = 24.7\ \text{A}$.

(c) Current through field coils is $(115\ \text{V}/66\ \Omega) = 1.74$ A.
Current through armature is $(10\ \text{V})/(5\ \Omega) = 2.0$ A. Total current is 3.74 A.

23. $N_p = N_s(V_p/V_s) = (9000)(120\ \text{V}/15000\ \text{V}) = 72$ turns.

24. $V_s = V_p(N_s/N_p) = V_p(110/280) = 0.393\ V_p$, i.e. a step down transformer.

25. Power is conserved. $(80\ \text{V})(I_p) = (220\ \text{V})(I_s)$. $I_s = 0.364\ I_p$.

26. We need $V_s/V_p = (12 \times 10^3\ \text{V})/(220\ \text{V}) = 55$. Thus $N_s/N_p = 55$.
If connected backwards it would step down to 4.0 V.

27. $V_s = V_p(N_s/N_p) = (120\ \text{V})(150/1000) = 18\ \text{V}$. $I_p = (I_sV_s)/V_p$ $(8.0\ \text{A})(18\ \text{V})/(120\ \text{V}) = 1.20\ \text{A}$.

28. (a) $I_s = (40\ \text{W})/(25\ \text{V}) = 1.6\ \text{A}$. As $I_s < I_p$, $V_s > V_p$, i.e. step up transformer.

(b) $V_s/V_p = I_p/I_s = (15/1.60) = 9.4$.

29. (a) $I = (30 \times 10^6\ \text{W})/(45 \times 10^3\ \text{V}) = 667$ A. Hence $\xi = 45 \times 10^3\ \text{V} + (667\ \text{A})(4\ \Omega) = 47.7\ \text{kV}$.

(b) Loss $= I^2R = (667)^2(4\ \Omega) = 1.78 \times 10^6$ W.
Total power $= 1.78 \times 10^6\ \text{W} + 30 \times 10^6\ \text{W} = 31.8 \times 10^6$ W.
Hence fraction lost is $(1.78 \times 10^6\ \text{W})/(31.8 \times 10^6\ \text{W}) = 0.0559$.

30. $I = P_T/V$. $P_L = I^2R_L = P_T^2R_L/V^2$.

31. According to formula in previous problem power saved is
$(50 \times 10^3\ \text{W})^2(0.200\ \Omega)[1/(120\ \text{V})^2 - 1/(1200\ \text{V})^2] = 3.4 \times 10^4$ W.
But 2% of power is lost. So 1.375×10^5 W $-$ $(0.02)(100 \times 10^3\ \text{W})$ = 135.5 kW.

32. $I = P_T/V = (200 \times 10^6\ \text{W})/(600 \times 10^3\ \text{V}) = 333.3$ A.
$R_L = P_L/I^2 = (0.02)(200 \times 10^6\ \text{W})/(333.3\ \text{A})^2 = 36\ \Omega$.
$A = \rho\ell/R = (2.65 \times 10^{-8}\ \Omega\cdot\text{m})(400 \times 10^3\ \text{m})/(36\ \Omega) = \underline{2.94 \times 10^{-4}\ \text{m}^2}$.
This is cross sectional area for design of line.

33. $\xi = (0.420\ \text{H})(15 \times 10^{-3}\ \text{A})/(0.250\ \text{s}) = 0.0252$ V.

34. $L = \mu_0N^2A/\ell = (4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(1 \times 10^4)^2(\pi)(0.016\ \text{m})^2/(0.40\ \text{m}) = \underline{0.253\ \text{H}}$.

35. $L = \Delta t\xi/\Delta I = (27.0 \times 10^{-3}\ \text{s})(8.50\ \text{V})/(59 \times 10^{-3}\ \text{A}) = \underline{3.89\ \text{H}}$.

36. $N = (L\ell/\mu_0A)^{\frac{1}{2}} = [(0.75 \times 10^{-3}\ \text{H})(0.09\ \text{m})/(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})/\pi/(0.005\ \text{m})^2]^{\frac{1}{2}} = \underline{827}$.

$N_2 = N_1(\mu_1/\mu_2)^{\frac{1}{2}} = (827)(10^{-3})^{\frac{1}{2}} = \underline{26.2}$.

37. $I_0 = \xi\Delta t/L = (75\ \text{V})(2 \times 10^{-3}\ \text{s})/(0.3\ \text{H}) = \underline{0.50\ \text{A}}$.

38. If we halve the diameter we double the number of turns and the length of the solenoid while the area decreases by a factor or four.
But from example (21–8), $L_2 = L_1(N_2^2/N_1^2)(A_2/A_1)(\ell_1/\ell_2) = L_1(4)(1/4)(1/2) = L_1/2$.
Inductance is half.

39. $\xi = (0.550\ \text{H})(4.50\ \text{A/s}) = 2.48$ V. Thus $V = (2.48\ \text{V}) + Ir = (2.48\ \text{V}) + (8\text{A})(3.00\ \Omega) = \underline{26.5\ \text{V}}$.

40. (a) By using Ampere's law, problem 20–44, we can show $B = \mu_0 NI/2\pi R$.
But $\xi = -\Delta BAN/\Delta t = (\mu_0 N^2 A/2\pi R)\Delta I/\Delta t$. A the area of the torus cross section in πr^2.
Hence $L = \mu_0 N^2 r^2/2R$ as required. The calculation assumes B is uniform in side the coil. This not true. The field varies as R changes by $+r$ or $-r$. However, as $R \gg r$ this is negligible. If w replace $N/2\pi r$ by n in both formulas then it is reasonable to assume that if we take some fractio of a piece of the circular solenoid that contains fN coils then $L = \mu_0 nAgfNn$. Replace N by N and n by N'/ℓ and we have the formula for the straight solenoid where N' is number of turns an ℓ is the length.

(b) $L - (4\pi \times 10^{-7}\ \mathrm{T \cdot m/A})\pi(800)^2(0.01\ \mathrm{m})^2/(0.60\ \mathrm{m}) = \underline{4.21 \times 10^{-4}\ \mathrm{H}}$.

41. (a) In series $= dI_1/dt = dI_2/dt = dI/dt$. $\xi = \xi_1 + \xi_2 = (L_1 + L_2)dI/dt$. $L = \underline{L_1 + L_2}$.

(b) In parallel $\xi/L_1 + \xi/L_2 = d(I_1 + I_1)/dt = dI/dt$. $1/L = \underline{1/L_1 + 1/L_2}$.

(c) In series two terms are added to $E = E_1 + MdI_2/dt + E_2 + MdI_1/dt$. But $I_1 = I_2$.
Hence $L = L_1 + L_2 + 2$ M. In parallel $E = L_1 dI_1/dt + MdI_1/dt$. $\xi = L_2 dI_2/dt + MdI_1/dt$.
Defining $E = L[dI_1/dt + dI_2/dt]$ gives $L = (M^2 - L_1L_2)(2M - L_1 - L_2)$.

42. $B = \mu_0(N_2/L_2)I_2$. $\Delta B/\Delta t = \mu_0(N_2/L_2)\Delta I_2/\Delta t$. $\xi_1 = (N_1\ell)(L_2)A\Delta B/\Delta t$. $\xi_1 = (N_1N_2/\ell)\mu_0 A\Delta I_2/\Delta t$.
Hence $M = \underline{N_1N_2\mu OA/\ell}$.

43. Using the results of problem 42 with μ_0 replaced by μ,
$M = N_1N_3\mu A/\ell = (300)(1500)(3000)(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A})(0.02)^2\pi/(0.40\ \mathrm{m}) = 5.33\ \mathrm{H}$.

(a) $E_2 = (5.33\ \mathrm{H})(4\ \mathrm{A})/(8 \times 10^{-3}\ \mathrm{s}) = \underline{2.66 \times 10^3\ \mathrm{V}}$.

(b) $M = \underline{5.33\ \mathrm{H}}$.

44. $-\Delta V = IR = LdI/dt$. Hence $(22.5\ \mathrm{V}) = (0.86\ \mathrm{A})R + L(3.40\ \mathrm{A/s})$ and also $16.2\ \mathrm{V} = (0.7\ \mathrm{A})R - L(1.80\ \mathrm{A/S})$. Solving $L = \underline{0.46\ \mathrm{H}}$ and $R = \underline{24.3\ \Omega}$.

45. Energy $= B^2 A\ell/^2\mu_0 = (0.6\ \mathrm{T})^2(\pi)(0.01\ \mathrm{m})^2(0.2\ \mathrm{m})/2/(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}) = \underline{9.00\ \mathrm{J}}$.

46. Energy $= LI^2/2 = (0.04\ \mathrm{H})(12\ \mathrm{A})^2/2 = \underline{2.88\ \mathrm{J}}$.

47. Energy $=$ (Volume)(Energy density)
$= 4\pi(6.37 \times 10^6\ \mathrm{m})^2(10 \times 10^3\ \mathrm{m})(0.5 \times 10^{-4}\ \mathrm{T})^2/(4\pi \times 10^{-7}\ \mathrm{T \cdot m/A})/2$
$= \underline{5.05 \times 10^{15}\ \mathrm{J}}$.

48. (a) For electric field density is $\varepsilon_0 E^2/2 = (8.85 \times 10^{-12}\ C^2/N\cdot m^2)(10^4\ V/m)^2/2 = 4.42 \times 10^{-4}\ J/m^3$.
For magnetic field $= B^2/2\mu_0 = (2T)^2/2/(4\pi \times 10^{-7}\ T\cdot m/A) = \underline{1.59 \times 10^6\ J}$.

(b) $E = B/(e_0\mu_0)^{\frac{1}{2}} = Bc = (2T)(3 \times 10^8\ m/s) = \underline{6 \times 10^8\ V/m}$.

49. If n time constants pass potential drops by e^{-n}. Hence we require $n = -\log 10^{-2} = 4.6$ or about 5.

50. $\Delta I/\Delta t = \xi/L = V/L$. In one time constant at this rate $I = (V/L)\Delta t = (V/L)(L/R) = V/R$.
This is I_0 because in the steady state $\Delta I/\Delta t = 0$ and Ohms law $I = V/R$ obtains.

51. $I = I_{max}[1 - e^{-t/\tau}]$
Let $f = I/I_{max}$
$f = 1 - e^{-t/\tau}$
$e^{-t/\tau} = 1 - f$
$-t/\tau = \ln(1 - f)$
$t = -\tau \ln(1 - f)$

(a) $f = 0.90$
$t = \underline{2.30\ \tau}$

(b) $f = 0.99$
$t = \underline{4.61\ \tau}$

(c) $f = 0.999$
$t = \underline{6.91\ \tau}$

52. (a) $0.5 = 1 - e^{-t/\tau}$
$e^{-t/\tau} = 0.5$
$t/\tau = -\ln(0.5) = 0.693$
$\tau = (2.66\ ms)/(0.693) = \underline{3.84\ ms}$

(b) $\tau = L/R$
$R = L/\tau = 350\ mH/3.84\ ms = \underline{91.2\ \Omega}$

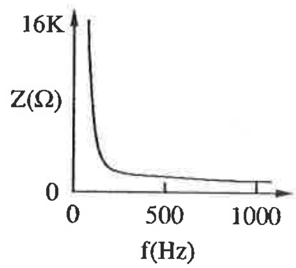
53. (a) $L = \mu_0 N^2 A/\ell$. If d is the thickness of the wire $Nd = \ell$.
Hence $N_1/d_1 = N_1(d_2/2) = \ell$ and $N_2 d_2 = \ell$, i.e. $N_1 = 2N_2$. Hence $L_1 = \underline{4L_2}$.

(b) Length of wire used is $(2\pi r)N$. Hence $(\ell_2/\ell_1) = (N_2/N_1) = (1/2)$
Area of wire (cross section) is proportional to d^2.
Hence $A_1/A_2 = (1/4)$. $R_2/R_1 = (\ell_2/\ell_1)(A_1/A_2) = 1/8$.
$(\tau_2/\tau_1) = (L_2/L_1)(R_1/R_2) = (1/4)(8) = \underline{2}$.

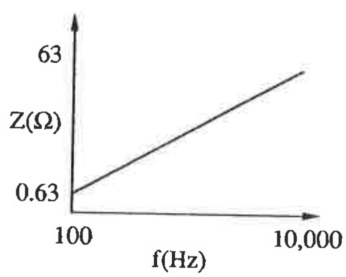
54. $f = (2000\ \Omega)/2\pi/(0.3\ \text{H}) = \underline{1061\ \text{Hz}}$.

55. $Z = (1/2\pi fC)$. $f = 1/(2\pi)/(7.20 \times 10^{-6}\ \text{F})/(300\ \Omega) = \underline{73.7\ \text{Hz}}$.

56.



57.



58. $Z = (2\pi fL) = (2\pi)(8.5 \times 10^{3})(100 \times 10^{-3}\ \text{H}) = \underline{5340\ \Omega}$.
$I_{rms} = V_{rms}/Z = (400\ \text{V})/(5340\ \Omega) = 74.9\ \text{mA}$.

59. $Z = V/I = (120\ \text{V})/(30\ \text{A})$. $L = Z/2\pi f = (4.00\ \Omega)/(2\pi)/(60\ \text{Hz}) = \underline{10.6\ \text{mH}}$

60. $Z = (I/2\pi fC) = 1/(2\pi)/(0.03 \times 10^{-6}\ \text{F})/(700\ \text{Hz}) = \underline{7.58 \times 10^{3}\ \Omega}$.
$I_0 = (2)^{\frac{1}{2}}\, I_{rms} = (2)^{\frac{1}{2}}(2 \times 10^{3}\ \text{V})/(7.58 \times 10^{3}\ \Omega) = \underline{0.373\ \text{A}}$.

61. $I_c = V/Z_c$. $I_R = V/R$. Thus $I_c/(I_c + I_R) = 1/(1 + 1/2\pi fCR)$.

(a) Percent current is (100)/[1 + 1/2π/(0.6 $\times$ 10^{-6} F)/(300 Ω)/(60 Hz)] = 6.35%.

(b) Percent is (100)/[1 + 1/2π/(0.6 $\times$ 10^{-6} F)/(300 Ω)/(60,000 Hz)] = 98.5%.

62. (a) Impedance of circuit is $[(1/2\pi fC)^2 + R^2]^{\frac{1}{2}}$ = $[(1/2\pi/(60\text{ Hz})/(2 \times 10^{-6}\text{ F}))^2 + (500\ \Omega)^2]^{\frac{1}{2}}$ = 1417 Ω.
Voltage drop across R is (500 Ω)(50 mV)/(1417 Ω) = 17.63 mV.

(b) Z = $[(1/2\pi/(60{,}000\text{ Hz})/(2 \times 10^{-6}\text{ F}))^2 + (500\ \Omega)^2]^{\frac{1}{2}}$ = 500.0088 Ω.
Voltage drop across R is (500 Ω)(50 mV)/(500.0088 Ω) = 49.9998 mV.
So capacitor is effective at eliminating 60 Hz signal.

63. (a) Z = $[(1000\ \Omega)^2 + (1/2\pi/(60\text{ Hz})/(2 \times 10^{-6}\text{ F}))^2]^{\frac{1}{2}}$ = 1661 Ω.

(b) Z = $[(1000\ \Omega)^2 + (1/2\pi/(2 \times 10^4\text{ Hz})/(2 \times 10^{-6}\text{ F}))^2]^{\frac{1}{2}}$ = 1000.008 Ω.

(a) Z = $[(20{,}000\ \Omega)^2 + ((0.30\text{ H})(2\pi)(60\text{ Hz}))^2]^{\frac{1}{2}}$ = 20.0 kΩ.

(b) Z = $[(20{,}000\ \Omega)^2 + ((0.30\text{ H})(2\pi)(3 \times 10^4\text{ Hz}))^2]^{\frac{1}{2}}$ = 60.0 kΩ.

65. Z = (120 V)/(70 $\times$ 10^{-3} A) = 1.71 kΩ.

66. Z = $[(8.7 \times 10^3\ \Omega)^2 + (1/2\pi/(60\text{ Hz})/(0.7 \times 10^{-6}\text{F}))^2]^{\frac{1}{2}}$ = 9.49 $\times$ 10^3 Ω.

(a) $I_{rms} = V_{rms}/Z$ = (120 V)/(9.49 $\times$ 10^3 Ω) = 12.6 mA.

(b) ϕ = $-$arcos (R/Z) = $-$ 23.5°.

(c) $P = I_{rms}V_{rms} \cos \phi$ = 1.39 W.

(d) For R, V = (12.6 mA)(8.7 $\times$ 10^3 Ω) = 110 V.
For C, V = (12.6 mA)/(60 Hz)/(2π)/(0.7 $\times$ 10^{-6} F) = 47.9 V.

67. $X_L = (2\pi fL) = (2\pi)(60\ \text{Hz})(600 \times 10^{-3}\ \text{H}) = 226\ \Omega$. $Z = [R^2 + Z^2]^{\frac{1}{2}} = 1221\ \Omega$.

(a) $I_{rms} = (120\ \text{V})/(1221\ \Omega) = \underline{98.3\ \text{mA}}$.

(b) $\phi = \text{arc cos}\ (R/Z) = \underline{10.7°}$.

(c) $P = I_{rms}V_{rms}\cos\phi = \underline{11.6\ \text{W}}$.

(d) $V_{rms} = (98.3 \times 10^{-3}\ \text{A})(1200\ \Omega) = \underline{117.9\ \text{V}}$ and for L, $V_{rms} = (0.0983\ \text{A})(226\ \Omega) = \underline{22.2\ \text{V}}$.

68. $Z = [(2000\ \Omega)^2 + [(754/\text{s})(3 \times 10^{-3}\ \text{H}) - 1/(754/\text{s})/(8 \times 10^{-6}\ \text{F})]^2]^{\frac{1}{2}} = 2007\ \Omega$.

Here we have used $\omega = f/2\pi = 754/\text{s}$. $I_{rms} = (3.5\ \text{V})/(2007\ \Omega)/(2)^{\frac{1}{2}} = 1.23\ \text{mA}$.
Power $= (V_{rms})(I_{rms})(R/Z) = \underline{3.04 \times 10^{-3}\ \text{W}}$.

69. $Z = (7\ \Omega)^2 + [(2\pi)(60\ \text{Hz})(60 \times 10^{-3}\ \text{H}) - 1/(2\pi)/(60\ \text{Hz})/(300 \times 10^{-6}\ \text{F})]^2]^{\frac{1}{2}}$

$= [(7\ \Omega)^2 + (13.8\ \Omega)^2]^{\frac{1}{2}} = 15.5\ \Omega$.

(a) $I_{rms} = (55\ \text{V})/(15.5\ \Omega) = \underline{3.56\ \text{A}}$.

(b) $\phi = \text{arc cos}\ (R/Z) = \underline{63.1°}$.

(c) $P = (3.56\ \text{A})(55\ \text{V})\cos 63.1° = \underline{88.7\ \text{W}}$.

70. $Z = [(4.1 \times 10^3\ \Omega)^2 + [(2\pi)(3 \times 10^3\ \text{Hz})(8 \times 10^{-3}\ \text{H}) - 1/2\pi/(3 \times 10^3\ \text{Hz})/(3000 \times 10^{-12}\ \text{F})]^2]^{\frac{1}{2}}$

$= [(4.1 \times 10^3\ \Omega)^2 + (-17533\ \Omega)^2]^{\frac{1}{2}} = 18006\ \Omega$.
$\phi = \text{arc sin}\ (-17533/18006) = \underline{-76.8°}$. $I_{rms} = (800\ \text{V})/(1.80 \times 10^4\ \Omega) = \underline{44.4\ \text{mA}}$.

71. $R = (Z^2 - X^2)^{\frac{1}{2}} = [(35)^2 - (30)^2]^{\frac{1}{2}}\ \Omega = \underline{18.0\ \Omega}$.

72. V_R is always in phasse with the instantaneous current. Its magnitude is equal to $IR = I_0R\cos\omega t$. V_L is 90° <u>ahead</u> of the current, or $\pi/2$ in radians. $V_L = I_0X_L\cos(\omega t + \pi/2) = I_0\omega L\cos(\omega t + \pi/2)$. $V_C = I_0/\omega C\cos(\omega t - \pi/2)$ because it is 90° behind.

73. $4\pi^2LC = (4\pi^2)(70 \times 10^{-6}\ \text{H})(1200 \times 10^{-12}\ \text{F}) = f^{-2}$. Hence $f = \underline{549\ \text{kHz}}$.

74. (a) $4\pi^2 LC = f^{-2}$ for resonance. Hence $L = (550 \times 10^3\ \text{Hz})^{-2}/4/\pi^2/(2500 \times 10^{-12}\ \text{F}) = 3.35 \times 10^{-5}$ H.
Hence for 1600 kHz $C = (1600 \times 10^{-3}\ \text{Hz})^{-2}/4/\pi^2/(3.35 \times 10^{-5}\ \text{H}) = \underline{295\ \text{pF}}$.

(b) $L = \underline{3.35 \times 10^{-5}\ \text{H}}$.

75. (a) $C = (3.6 \times 10^3\ \text{Hz})^{-2}/4/\pi^2/(3.6 \times 10^{-3}\ \text{H}) = 0.543\ \mu\text{F}$.

(b) $Z = R$ on resonance. $I_0 = V/R = (50\ \text{V})/(2\ \Omega) = \underline{25\ \text{A}}$.

76. (a) $f^{-2} = 4\pi^2 LC$. Hence $f = \underline{22.6\ \text{kHz}}$.

(b) When $Q = 0 = -LdI/dt$, I is maximum. Energy stored in inductance is $LI^2/2 = QV/2$ or $V^2C/2$.

Hence $I = V(C/L)^{\frac{1}{2}} = (100\ \text{V})(660 \times 10^{-12}\ \text{F})^{\frac{1}{2}}/(75 \times 10^{-3}\ \text{H})) = \underline{9.38\ \text{mA}}$.

(c) $E = V^2C/2 = (100\ \text{V})^2(660 \times 10^{-12}\ \text{F})/2 = \underline{3.3 \times 10^{-6}\ \text{J}}$.

77. $N_p/N_s = (Z_p/Z_s)^{\frac{1}{2}} = (30000/8)^{\frac{1}{2}} = \underline{61.2}$

. $R = (8)(8)/(8 + 8) = 4\ \Omega$. Connected to $\underline{4\ \Omega}$ output terminal.

79. (a) Yes because the flux through the loop was originally zero. It has now increased because an N-pole has appeared outside it.

(b) Immediately.

(c) As soon as the current stops changing in the first coil.

(d) A N-pole is induced, so current is counter-clockwise.

(e) Yes.

(f) The two induced N-poles face on another so force is repulsive.

80. $\xi = \pi(0.05\ \text{m})^2(0.355\ \text{T})/(0.07\ \text{s}) = 0.0398$ V. This voltage acts for 0.07 s.
Energy = Power × time = $(V^2/R)t = (0.0398\ \text{V})^2(0.07\ \text{s})/(6.60\ \Omega) = \underline{1.68 \times 10^{-5}\ \text{J}}$.

81. $\xi = NA2B/\Delta T$. $Q = I\Delta t = \xi\Delta t/R = NA2B/R$. Hence $B = QR/2NA$.

82. (a) The voltage difference at the delivery end is
$32\text{ kV} - IR - (0 + IR) = (32000\text{ V} - 2(800\text{ A})(0.8\ \Omega)) = \underline{30720\text{ V}}$.

(b) Power input $= IV = (800\text{ A})(32000\text{ V}) = \underline{2.56 \times 10^7\text{ W}}$.

(c) Power loss is $I^2(R + R) = 2(800\text{ A})^2(0.8\ \Omega) = \underline{1.024 \times 10^6\text{ W}}$.

(d) Power delivered is IV delivered $= (800)(30720\text{ V}) = \underline{2.46 \times 10^7\text{ W}}$.

83. There must be a force of friction equal to 250 N on the drive wheel. The motor must exert a torque equal to $(250\text{ N})(0.25\text{ m}) = 62.5\text{ N}\cdot\text{m}$.

(a) But $\tau = NIAB$, eq (20–6), hence $I = (62.5\text{ N}\cdot\text{m})/(300)/(0.1\text{ m})/(0.15\text{ m})/(0.60\text{ T}) = \underline{23.1\text{ A}}$.

(b) $P = (250\text{ N})(8.33\text{ m/s}) = 2083\text{ W}$. This is power delivered.
Power wasted in armatures is $I^2R = 536\ R$.
Power drained from battery is $(120\text{ V})(23.1\text{ A}) = 2778\text{ W}$.
Thus $R = (2778\text{ W} - 2083\text{ W})/(536\text{ A}^2) = 1.296\ \Omega$.
Voltage across armature is $IR = (23.1\text{ A})(1.296\ \Omega) = 30.0\text{ V}$.
Thus back *emf* is $(120 - 30.0)\text{V} = 90\text{ V}$. We could have deduced this directly from the power delivered if we knew that this was equal to (current drawn)(back *emf*),
i.e. back *emf* $= (2083\text{ W})/(23.1\text{ A}) = \underline{90\text{ V}}$.

(c) Power wasted is $2778\text{ W} - 2083\text{ W} = \underline{695\text{ W}}$.

(d) Efficiency $= (2083\text{ W})/(2778\text{ W}) = 0.750$ or $\underline{75.0\%}$.

84. $\cos\phi = R/Z = 0.866$. $Z = (120\text{ V})/(6.4\text{ A}) = 18.75\ \Omega$. $R = \underline{16.24\ \Omega}$.
$\phi = -30^\circ$ hence other element is a capacitance $C = 1/2\pi fZ \sin\phi = \underline{283\ \mu\text{F}}$.

85. $Z = R$, i.e. $2\pi fL = 1/2\pi fC$, i.e. $C = 1/(130 \times 10^{-3}\text{ H})/(2\pi)^2/(2360\text{ Hz})^2 = \underline{3.50 \times 10^{-8}\text{ F}}$.

86. $X_L = 2\pi fL$

$$I = \frac{V}{X_L} \Rightarrow 1.2\text{ A} = \frac{110\text{ V}}{X_L} \Rightarrow X_L = 91.67\ \Omega$$

$91.67 = (2\pi)(60\text{ Hz})L$
$L = \underline{0.24\text{ H}}$.

87. At resonance $2\pi fL = \dfrac{1}{2\pi fC}$.

$$L = \frac{1}{(2\pi f)^2C} = \frac{1}{(2\pi \times 18 \times 10^6\text{ Hz})^2 \times 220 \times 10^{-12}\text{ F}}$$

$L = 3.55 \times 10^{-7}$ H
but $L = \mu_0 N^2 A$/Length of wire

$$3.55 \times 10^{-7}\text{ H} = \frac{(4\pi \times 10^{-7}\text{ T}\cdot\text{m/A})N^2 \times \pi \times (0.55 \times 10^{-3}\text{ m})^2}{12\text{ m}}$$

$$N^2 = \frac{(3.55 \times 10^{-7}\text{ H})(12\text{ m})}{(4\pi \times 10^{-7}\text{ T}\cdot\text{m/A})\pi(0.55 \times 10^{-3}\text{ m})^2}$$

N = <u>1888.7 turns</u>.

88. $R = (36\text{ V})/(2.5\text{ A}) =$ <u>14.4 Ω</u>. $Z = (120\text{ V})/(3.8\text{ A}) = 31.6\ \Omega$.

$X_L = (Z^2 - R^2)^{\frac{1}{2}} = 28.1\ \Omega. = (2\pi)(60\text{ Hz})L$. Hence $L =$ <u>0.0745 H</u>.

89. (a) $I_{rms} = V_{rms}/Z$. $V_R = V_{rms}(R/Z)$. $V_C = V_{rms}/\omega CZ$. But on resonance $\omega^2 = 1/LC$ or $\omega = 1/(LC)^{\frac{1}{2}}$.

Hence $V_C = V_{rms}(L/C)^{\frac{1}{2}}/Z$. Hence $Q = (V_C/V_R) = (L/C)^{\frac{1}{2}}/R$.

(b) $4\pi^2f^2LC = 1$. Hence $L =$ <u>2.53 μH</u>.

Hence $R = Q^{-1}(L/C)^{\frac{1}{2}} = 10^{-3}[(2.53 \times 10^{-6}\text{ H})/(0.01 \times 10^{-6}\text{ F})]^{\frac{1}{2}} =$ <u>0.0159 Ω</u>.

Chapter 22

1. $I_0 = \varepsilon_0 A\Delta E/\Delta t = (8.85 \times 10^{-12}\ \text{F/m})(0.02\ \text{m})^2(2.0 \times 10^6\ \text{V/m}\cdot\text{s}) = \underline{7.08 \times 10^{-9}\ \text{A}}$.

2. $I = \Delta Q/\Delta t = \varepsilon_0 A\Delta E/\Delta t$. Hence $\Delta E/\Delta t = (4.0\ \text{A})/(8.85 \times 10^{-12}\ \text{F/m})/(0.01\ \text{m})^2 = \underline{4.52 \times 10^{15}\ \text{V/m}\cdot\text{s}}$.

3. From eq(22–1), $(B2\pi r) = 0 + \mu_0\varepsilon_0\Delta\phi E/\Delta Q/\Delta t = \mu_0\Delta Q/\Delta t$.
Hence $B = (4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(25 \times 10^{-3}\ \text{C/s})/2\pi/(0.12\ \text{m}) = \underline{4.17 \times 10^{-8}\ \text{T}}$.

4. From section 22–2.

$$I_D = \varepsilon_0 A \frac{\Delta E}{\Delta t} \text{ but } E = V/d.$$

$$I_D = \varepsilon_0 A \frac{\Delta(V/d)}{\Delta t}, \text{ for constant } d$$

$$I_D = \frac{\varepsilon_0 A}{d}\frac{\Delta V}{\Delta t} = C\frac{\Delta V}{\Delta t}.$$

5. For $r < R$, eq (22–1) gives $B2\pi r = \mu_0\varepsilon_0\Delta\phi E/\Delta t = \mu_0\varepsilon_0\pi r^2\Delta E/\Delta t$ as $I_C = 0$ and $\phi_B = AE = \pi r^2 E$ assuming E uniform. $B = \mu_0\varepsilon_0 r\Delta E/\Delta t/2$. If $r \geq R$, E is zero outside capacitor (approximately) then $\phi_B = \pi R^2 E$ and $B = \mu_0\varepsilon_0 R^2\Delta E/\Delta t/r/2$.

6. $B = E/c = (0.45 \times 10^{-4}\ \text{V/m})/(3.0 \times 10^8\ \text{m/s}) = \underline{1.5 \times 10^{-13}\ \text{T}}$.

7. $E_{rms} = cB_{rms} = (3 \times 10^8\ \text{m/s})(7.75 \times 10^{-9}\ \text{T}) = \underline{2.33\ \text{V/m}}$. $f = \underline{80.0\ \text{kHz}}$.
E field is horizontal N–S.

8. $\lambda = c/f = (3 \times 10^8\ \text{m/s})/(12.25 \times 10^9\ \text{Hz}) = \underline{0.0245\ \text{m}}$.

9. $f = (3 \times 10^8\ \text{m/s})/(0.025\ \text{m}) = \underline{1.20 \times 10^{10}\ \text{Hz}}$.

10. For the sound to reach the balcony takes $d/v = (50\ \text{m})/[331\ \text{m/s} + (0.6\ \text{m/s}\cdot{}^\circ\text{C})(20\ {}^\circ\text{C})] = 0.146$ s. For the electrical signal to reach the radio takes $(3 \times 10^6\ \text{m})/(3 \times 10^8\ \text{m/s}) = 0.01$ s. Person by radio hears 0.136 s sooner.